Stress control of hydrogenated amorphous silicon nitride films deposited by plasma-enhanced chemical vapor deposition

Hidenori Gamo[1], Hideyuki Eguchi[1], Toshiaki Kurosu[1], Kiyoharu Nakagawa[2,4], Mikka Nishitani-Gamo[3], and Toshihiro Ando[4]

[1]Technical Research Institute, Toppan Printing Co., Ltd., 4-2-3 Takanodaiminami, Sugito, Saitama 345-8508, Japan,
[2]Japan Society for Promotion of Science (JSPS),
[3]Center for Tsukuba Advanced Research Alliance (TARA), University of Tsukuba, Tsukuba, Ibaraki 305-8577, Japan, and
[4]National Institute for Materials Science (NIMS), 1-1 Namiki, Tsukuba, Ibaraki 305-0044, Japan.

Hydrogenated amorphous silicon nitride (a-SiN_x:H) films are attracted increased interest with respect to wide applications in silicon-device and their process technologies, such as gate insulator, passivation layer in thin-film transistor, and membranes for e-beam or X-ray lithography masks. Plasma-enhanced chemical vapor deposition (PECVD) method is usually employed to produce the a-SiN_x:H films. In the a-SiN_x:H films applications, the remaining stress must be controlled in the deposition process to form free-standing films by preventing from cracks.

In this paper, we demonstrate the results on the relationships between the stress and structure or optical properties such as photoluminescence (PL), optical band gap and refractive index of a-SiN_x:H films. We found that the PL spectrum were clearly correlated with the stress of deposited a-SiN_x:H films. We propose that the PL measurement is a very useful to estimate the stress and its distribution of the a-SiN_x:H films in very small points of 1µm without any destruction.

A-SiN_x:H thin-films were deposited at 400˚C on single-crystal silicon (c-Si) substrates using SiH_4-NH_3 mixtures in H_2 at a pressure of 1 Torr by PECVD. Total and SiH_4 gas flow rate are set to be constant at 262 sccm and 5 sccm, respectively. The stress, PL, optical band gap, and refractive index were investigated as a function of the NH_3 flow ratio in the range of 4-15 % in the gas phase. The stress of deposited films was measured by wafer curvature method using Tencor model FLX-2320. The PL spectra were measured by using Renishaw 2000 micro-Raman spectrometer. The 325 nm emission line from an He-Cd laser was used to excite the luminescence.

Increased tensile stress subsequent to a reduction in the compressive stress was observed with increasing NH_3 gas flow ratio, as shown in Fig. 1. It was found that very low value of the stress less than 200MPa was observed in the range of 5-8% of NH_3 flow ratio. Ratherford backscattering spectroscopy (RBS) determined the stoichiometric composition of the all a-SiN_x:H films prepared in this study to be x=1.33. Figure 2 shows relationships between the NH_3 flow ratio and the relative intensity of N-H bond analyzed by FT-IR. The intensity of N-H bonds increased with increasing NH_3 flow ratio. These results show that the stress of a-SiN_x:H films are caused by not the composition of SiN_x but affected by the incorporated N-H bonds. Figure 3 shows PL spectra of a-SiN_x:H films deposited as a function of the flow ratio of NH_3 in total flow rate. Very strong PL was observed in the a-SiN_x:H films which have compressive stress, on the other hand, the tensile-stressed a-SiN_x:H films exhibited weak PL. The peak of the PL spectra were ranged in 570-580 nm (about 2.2eV in energy) from all a-SiN_x:H films. We conclude that the PL intensity strongly relates with the stress of the a-SiN_x:H films.

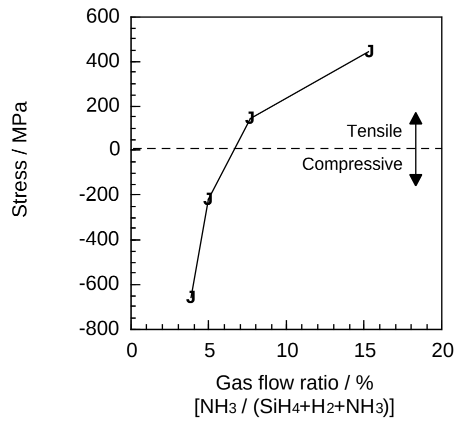

Fig. 1 Stress of deposited a-SiN_x:H films.

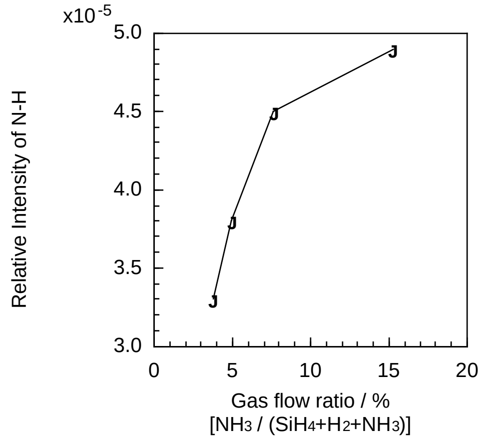

Fig. 2 Relative intensity of N-H by FT-IR of deposited a-SiN_x:H films.

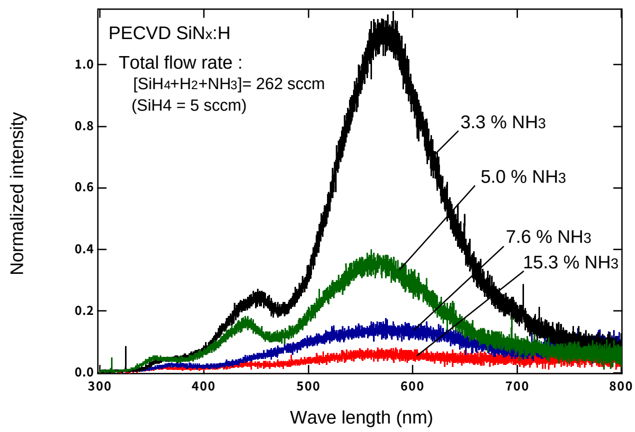

Fig. 3 Photoluminescence of deposited a-SiN_x:H films.